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Level 2 Chemistry, 2015

91164 Demonstrate understanding of bonding, structure, properties and energy changes

9.30 a.m. Monday 23 November 2015
Credits: Five

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of bonding, structure, properties and energy changes.	Demonstrate in-depth understanding of bonding, structure, properties and energy changes.	Demonstrate comprehensive understanding of bonding, structure, properties and energy changes.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

A periodic table is provided on the Resource Sheet L2–CHEMR.

If you need more room for any answer, use the extra space provided at the back of this booklet and clearly number the question.

Check that this booklet has pages 2–12 in the correct order and that none of these pages is blank.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

Excellence

TOTAL 21

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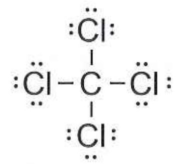
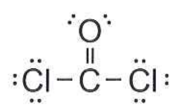
QUESTION ONE

(a) Draw the Lewis structure (electron dot diagram) for each of the following molecules.

Molecule	O_2	OCl_2	CH_2O
$2O = \frac{12}{2} = 6$ pairs **Lewis structure**	~~O=O~~ :Ö=Ö:	O=6 2Cl=14 $\frac{26}{2}$=10 pairs :C̈l–Ö–C̈l:	C=4 2H=2 O=6 $\frac{12}{2}$=6 pairs :Ö=C(H)–H

(b) Carbon atoms can bond with different atoms to form many different compounds.

The following table shows the Lewis structure for two molecules containing carbon as the central atom, CCl_4 and $COCl_2$. These molecules have different bond angles and shapes.

Molecule	CCl_4	$COCl_2$
Lewis structure		

Evaluate the Lewis structure of each molecule to determine why they have different bond angles and shapes.

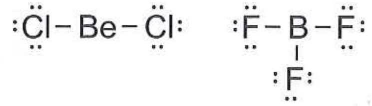
In your answer, you should include:

- the approximate bond angle in each molecule
- the shape of each molecule
- factors that determine the shape and bond angle for each molecule.

The factors that determine the ~~shape and~~ bond angle of the molecule is the number of repulsions around the central C atom. The shape is determined by how many of these repulsions are bonded to the central C atom or if they are just lone pairs. CCl4 has 4 repulsions around the central C atom. The repulsions are arranged in a tetrahedral arrangement to allow for maximum distance and therefore minimum repulsion between them. Since ~~4~~ all of these repulsions are ~~bond covalent~~ single bonds between the Cl atoms and the central C atom and there are no ~~lone~~ unbonded (lone) electron pairs, the shape of the molecule is a tetrahedral with a bond

angle of 109.5° due to its 4 repulsions. COCl2 has three repulsions around the central C atom. These repulsions are arranged in a trigonal planar arrangement for maximum distance and therefore minimum repulsion between them. Since the Cl atoms 2 of ~~these~~ form a single bond with the central C atom and the O atom forms a double bond with the central C atom, all repulsions form bonds and so there are no unbonded (lone) pairs so the shape of the molecule is a trigonal planar and the bond angle is 120° because it only has 3 repulsions.

(c) $BeCl_2$ and BF_3 are unusual molecules because there are not enough electrons for the central atoms, Be and B, to have a full valence shell. Their Lewis structures are shown below.



Both molecules have the same polarity.

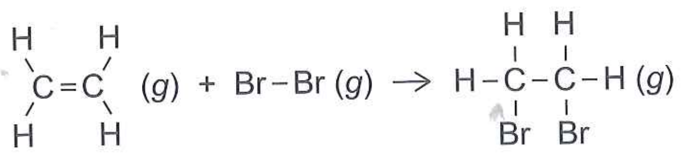
Circle the word that describes the polarity of these molecules.

polar **non-polar**

Justify your choice.

A non-polar molecule has an even distribution of electrons throughout the molecule and so there is no charge separation or molecular dipole because of this. BeCl2 is a linear molecule with a bond angle of 180° due to its 2 repulsions about the Be atom. The molecule is made up of polar Be–Cl bonds. These are polar bonds as Cl is more electronegative than Be. ~~An~~ Electronegativity is an atom's tendency to attract the shared electrons within the covalent bond so the electrons are more attracted to Cl than Be. This causes Cl to be slightly negative and Be to be slightly positive and so the bonds are polar due to this charge separation. The molecule is non-polar because the polar Be–Cl bonds are arranged symmetrically around the central Be atom and so the effects of the polar bonds are cancelled, it BeCl2 molecule is overall non-polar. BF3 is a trigonal planar molecule with bond angle of 120° due to 3 repulsions about the central B atom. ~~The~~ It consists of polar B–F bonds as F is more electronegative than B and so →

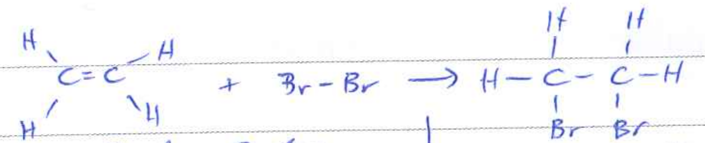
(d) Ethene gas, $C_2H_4(g)$, reacts with bromine gas, $Br_2(g)$, as shown in the equation below.



Calculate the enthalpy change, $\Delta_r H°$, for the reaction between ethene and bromine gases, given the average bond enthalpies in the table below.

Show your working and include appropriate units in your answer.

Bond	Average bond enthalpy / kJ mol^{-1}
Br–Br	193
C–C	346
C=C	614
C–Br	285
C–H	414



Bonds Broken	Bonds Made
C=C = 614	C–C = −346
4× C–H = 4×414	4× C–H = 4×−414
Br–Br = 193	2× C–Br = 2× −285
2463	−2572

$\Delta_r H = 2463 + (-2572)$

$= 2463 - 2572$

$= -109$ kJmol^{-1}

~~of 109 kJ released~~

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QUESTION TWO

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(a) Hand warmers contain a supersaturated solution of sodium ethanoate which, when activated, crystallises and releases heat.

Circle the term that best describes this reaction.

exothermic **endothermic**

Give a reason for your choice.

Exothermic reactions release energy. Since hand warmers release energy when activated, the reaction with sodium ethanoate must be exothermic as heat energy is released.

(b) (i) Glucose is made in plants during photosynthesis when carbon dioxide gas, $CO_2(g)$, and water, $H_2O(\ell)$, react to produce glucose, $C_6H_{12}O_6(aq)$, and oxygen gas, $O_2(g)$. The photosynthesis reaction can be represented by the following equation:

$$6CO_2(g) + 6H_2O(\ell) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g) \quad \Delta_r H° = 2803 \text{ kJ mol}^{-1}$$

Circle the term that best describes this reaction.

exothermic **endothermic**

Give a reason for your choice.

The reaction is endothermic as the change in ~~e~~ enthalpy ArH is 2803 kJ mol^{-1} meaning the ~~H products~~ ~~pro~~ ~~e~~ enthalpy ~~of~~ of the products is greater than the enthalpy of the reactants as ArH = Hproducts − Hreactants so the reaction absorbs energy which means it is endothermic.

(ii) Calculate how much energy is absorbed or released in the photosynthesis reaction if 19.8 g of carbon dioxide gas, $CO_2(g)$, reacts completely with excess water, $H_2O(\ell)$, to form glucose, $C_6H_{12}O_6(aq)$, and oxygen gas, $O_2(g)$.

Show your working and include appropriate units in your answer.

$M(CO_2) = 44.0$ g mol^{-1}

$n = \frac{m}{M}$ ~~so~~ $n(CO_2) = \frac{19.8}{44.0} = 0.45$ mol

In the equation,

6 mol CO_2 reacts with 6 mol H_2O ~~to form 1 C6H12O6 and 6 mol of O2~~

So 0.45 mol CO_2 reacts with 0.45 mol H_2O to form glucose & Oxygen

If 6 mol CO_2 takes 2803 kJ to react with 6 mol H_2O

then 1 mol CO_2 takes $\frac{2803}{2}$ kJ to react with 1 mol H_2O
1401.5 kJ

so 0.45 mol CO_2 takes 1401.5×0.45 kJ to react with 0.45 mol CO_2
= 630.675 ≈ 631 (3sf)

~~That~~ To react 19.8 g of CO_2 with H_2O completely to form glucose and oxygen, the energy absorbed is 631 kJ.

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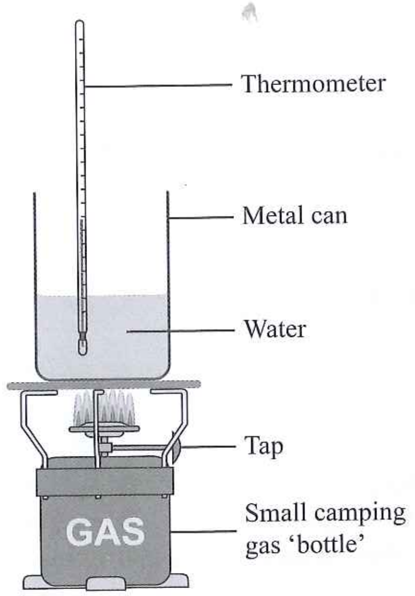
(c) A small camp stove containing butane gas, $C_4H_{10}(g)$, is used to heat some water, as shown in the diagram below. A student measures the temperature change in the water and calculates that when 3.65 g of butane is combusted, 106 kJ of heat is released.



The reaction for the combustion of butane is shown in the equation below.

$$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(\ell)$$

(i) Calculate the enthalpy change ($\Delta_r H$) for this reaction, based on the above measurements.

$M(C_4H_{10}) = 58.0 \text{ g mol}^{-1}$

$n = \frac{m}{M}$ $n = \frac{3.65}{58.0} = 0.06~~3~~29$ mol (3sf)

If 0.0629 mol C_4H_{10} releases 106 kJ to combust

~~In equation~~ The 1 mol C_4H_{10} will ~~take~~ release $\frac{106}{0.0629}$ kJ ~~to combust~~ $= 1684.4$ kJ

So for 2 mol C_4H_{10} in the reaction it will ~~take~~ release

$1684.4 \times 2 = 3368.8 \approx 3370$ kJ (3sf)

For the reaction the enthalpy change is $\Delta_r H = -3370$ kJ/mol

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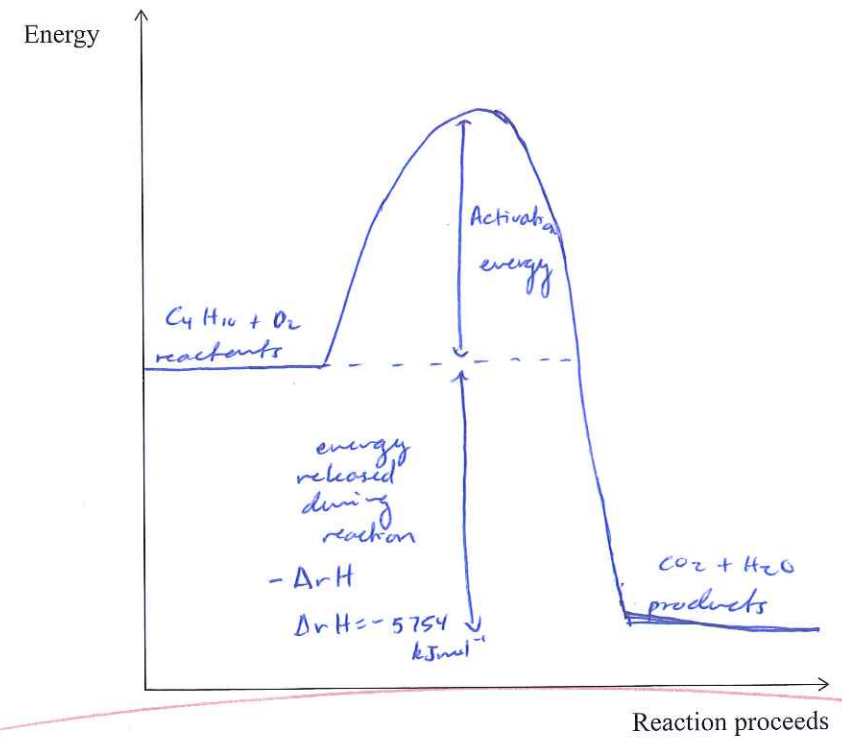
(ii) The accepted enthalpy change for the combustion reaction of butane gas, $C_4H_{10}(g)$, is $\Delta_r H = -5754 \text{ kJ mol}^{-1}$.

Explain why the result you calculated in part (c)(i) is different to the accepted value.

In your answer, you should include at least TWO reasons.

The result I calculated in c)i) is different as the heat released for 3.65g of C_4H_{10} is only a measurement made by the student. It is different as different factors could have influenced the student's measurement like errors in reading the thermometer or the temperature of the room could have affected the measurements of the change of heat in the water. The availability of the oxygen needed for ~~butad~~ butane to completely combust may have differed too as there may not have been enough O_2 for complete combustion in the student's reaction ~~to completely com react the~~ with O_2 and so energy released is different so the $\Delta_r H$ values differ.

(iii) Complete, including labels, the energy diagram for the combustion of butane gas showing reactants, products, and the change in enthalpy.



(iv) Butane gas is a useful fuel because when it undergoes combustion, energy is released.

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Explain why energy is released in this reaction, in terms of making and breaking bonds.
No calculations are required.

In a chemical reaction, energy changes also occur because ~~the atoms~~ bonds are broken and made to rearrange the atoms of the reactants for the formation of the products. Energy is released in the ~~com~~ butane's combustion reaction with O_2 ~~as the rea~~ it takes less energy to break the bonds between the C_4H_{10} and O_2 than to make the bonds for CO_2 and H_2O. Energy is absorbed to break the bonds between the ~~reactant~~ C_4H_{10} and O_2 as energy is needed to break the strong covalent bonds but energy is released to form the bonds for the formation of CO_2 and H_2O. Energy is overall released in this reaction as the reaction releases more energy to form H_2O & CO_2 as products than to absorb the energy to break the bonds between C_4H_{10} & O_2.

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QUESTION THREE

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(a) Complete the table below by stating the type of solid, the type of particle, and the attractive forces between the particles in each solid.

Solid	Type of solid	Type of particle	Attractive forces between particles
$Cu(s)$ (copper)	metallic ~~substance~~ solid	atoms	metallic bonding (non-directional)
$PCl_3(s)$ (phosphorus trichloride)	molecular ~~substance~~ solid	molecules	weak Van der Waals Forces
$SiO_2(s)$ (silicon dioxide)	3D covalent network solid	atoms	strong covalent bonds
$KCl(s)$ (potassium chloride)	Ionic solid	ions	ionic bonds

(b) Phosphorus trichloride, PCl_3, is a liquid at room temperature, and does not conduct electricity.

Explain these two observations in terms of the particles, structure, and bonding of PCl_3.

PCl_3 is a molecular substance. It consists of PCl_3 molecules held together by weak Van der Waals forces. PCl_3 is liquid at room temperature due to its low melting point. PCl_3 has a low melting point as melting point is determined by the strength of the attractive forces holding the substance together. The forces between the PCl_3 molecules are weak Van der Waals forces and take little energy to overcome so PCl_3 has a low melting point. This is why ~~the~~ PCl_3 is liquid at room temperature as the weak Van der Waals forces are overcome at room temperature. PCl_3 does not conduct electricity. For a substance to conduct electricity, it must have free moving charged particles. PCl_3 is a molecule. ~~There are~~ P atom is covalently bonded to 3 Cl atoms. Their valence electrons are simultaneously attracted to the positive nuclei of the P and Cl atoms and so they are not transferred but shared. So PCl_3 does not contain free moving charge particles and so will not conduct electricity.

(c) Consider each of the solids copper, Cu, silicon dioxide, SiO_2, and potassium chloride, KCl.

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Complete the table below by identifying which of these solids have the listed physical properties:

Physical properties	Solid
The solid is insoluble in water and is malleable.	Copper, Cu
The solid is soluble in water and is not malleable.	Potassium chloride, KCl
The solid is insoluble in water and is not malleable.	silicon dioxide, SiO_2

Justify TWO of your choices in terms of the particles, structure, and bonding of these solids. You may use diagrams in your justification.

Copper is insoluble in water and is malleable and Silicon Dioxide is insoluble in water and not malleable. Copper is a metallic solid. It consists of Cu atoms tightly packed together in a fixed 3D lattice. The Cu atoms are held together by non-directional metallic bonding. SiO_2 is a 3D covalent network solid. ~~The solid is insoluble in water because~~ It consists of Si and O atoms covalently bonded so that Si is bonded to ~~for~~ 4 O atoms and O atoms are bonded to 2 Si atoms in a repeating tetrahedral arrangements. For a substance to be soluble in water, it must have similar strength to the forces of water as the ~~bonds~~ forces of the ~~solute~~ substance's particles have to be ~~broken~~ overcome and the ~~bonds~~ forces between the H_2O molecules have to be overcome for new forces to come into being between water molecules and the ~~solute~~ substance's particles. Copper and SiO_2 are both insoluble as the strength of the forces holding their particles together are too strong for the water molecules to pull the ~~Cu ato~~ particles from their fixed 3D lattice. The metallic bonds between the Cu atoms ~~is~~ are too strong ~~as well as~~ The covalent bonds between the Si and O atoms are also too strong to ~~over~~ be overcome so they ~~do~~ are not soluble in water. Cu is malleable because ~~of~~ the Cu atoms are arranged in layers. And these

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Extra paper if required.
Write the question number(s) if applicable.

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1c the electrons in the covalent bond are more attracted to F than B. Making F slightly negative and B slightly positive. These polar ~~bon~~ B-F bonds ~~are~~ are arranged symmetrically around the B atom in such a way that the effects of these polar B-F bonds are cancelled and so BF_3 is overall a non-polar molecule.

3c) layers are held together by non-directional metallic bonding. This means that the Cu atoms do not need specific locations in relation to ~~if~~ the neighbouring Cu atoms in the solid. So when copper metal is hammered, the layers of Cu atoms can easily slip over each other. SiO_2 is not malleable as the covalent bonds between the Si atoms and O atoms are strong. So when hammered they are unaffected as the strong covalent bonds hold the atoms in place. This is why they are ~~strongly fixed~~ is able to be in a fixed geometric pattern, as the covalent bonds do not allow for movement and why SiO_2 is a hard substance.

Extra paper if required.
Write the question number(s) if applicable.

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